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(6) MEASURES OF EFFECTIVENESS

FOR CAMOUFLAGE

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SUMMARY

Camouflage is a broad concept incorporating the notions of hiding, blending, disguising, or decoying to achieve countersurveillance (CS) and counter target acquisition (CTA). Both concealment and deception are involved. The purpose of camouflage is by passive means to deny, degrade, deceive, delay or otherwise interfere with hostile surveillance of friendly forces. The systems devised to accomplish these purposes are supportive rather than primary in their combat roles. Their contribution to accomplishing the combat mission is indirect, such as enhancing survival of primary firepower, enabling movement with reduced materiel losses, and reducing casualties. Camouflage measures of effectiveness (MOE) thus must measure both the direct performance of CS/CTA systems, in terms of reduced target detection/recognition/identification, and the indirect or consequential performance effects, in terms of increased survival and reduced materiel/personnel losses.

For a given camouflage concept, there is no single MOE that will describe all the qualities that are desired. Different perspectives or perceptions of the camouflage and deception needs cover too broad a range. Four levels of MOE seem appropriate, viz., design, system operations, tactical operations, and force. The Design level utilizes measures of quality and performance to assess the feasibility, physical characteristics, and technology of the materials, components, and systems proposed for camouflage. This level might easily be divided into two parts to distinguish between (1) the physical evaluation of design alternatives and (2) the application evaluation of design performance in the underlying technical areas, such as electromagnetics optics, radiometry, photometry, and human psychometrics or psychophysics. The System operation level extends the design viewpoint further into the mission configuration, utilizing MOE related directly to target perceptibility by sensor systems. The Tactical operations level MOE introduce the engagement environment in some detail to assess probabilities of detection, recognition, identification, and survival in events where camouflage may be employed. The Force level MOE assess combat effectiveness when camouflage and deception are added to the force and are expressed in terms of survivability of friendly forces, exchange ratios, resources consumed or lost, and territory gained or lost. If the processes of

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intelligence and decision/action deriving from surveillance were better understood, this level might be divided into two parts to distinguish between (1) measures of camouflage effectiveness in terms of intelligence collection time/effort as interpretation-processing and (2) the combat results MOE.

The tools available for camouflage assessments in this assessment hierarchy, ranging from the lowest, most detailed technology level to the highest aggregated combat-outcome level, reflect the character and perspective of analysis at each level. They include analytical (or physical) models, design/laboratory experiments, one-on-one models and simulations of sensor-target interactions, controlled laboratory/field experiments, high-resolution models of the combat processes, controlled field experiments/exercises, and war games. The time and costs associated with experimental assessments are highly sensitive to the large number of variables and parameters involved in the full range of experiments that may be needed for the complex camouflage problem. Realistically, most of the assessment burden will have to be borne by analysis, modeling, simulation, and gaming techniques. Effectiveness test and evaluation, including laboratory/field experiments, can provide essential data to verify the design, validate and calibrate the analysis work, verify the systems, tactical, and force performance measures, and conduct maneuver trials for demonstration and acceptance judgments of camouflage systems.

The status of the one-on-one models, the higher-echelon tactical models, and the gaming methods is an important consideration. These models and methods serve as transition media from one MOE level to another and must be developed to a point where they have broad credibility and acceptance. The one-on-one models examined have limited but useful capabilities for analyzing and assessing camouflage and deception concepts or designs. Modification and improvement seems feasible to extend their applicability and effectiveness. There is room for, and a need for, the development of similar models of limited situations to extend assessment capabilities in this category.

The high-resolution combat-analysis models now in use by the U. S. Army have some capabilities, though marginal, for camouflage and deception assessment. Modification and improvement of these capabilities, along with sensitivity tests of these models, can provide MOE and useful assessment tools.

The gaming methods and war games now in use by the U. S. Army appear insensitive to camouflage and deception factors, except in the case of direct input by game control. These methods are costly to implement and operate, and cannot presently accommodate the intelligence-processes analysis that is critical for assessment of camouflage and deception. There is need for development of intelligence analysis capabilities to support measurement of the counter decision/action effects and the military worth of camouflage and deception in order to conduct realistic war game analysis of these influences on battle outcomes.

MEASURES OF EFFECTIVENESS FOR CAMOUFLAGE(1)

by

D. L. Farrar

Introduction

New importance is being attached to current and future U. S. Army capabilities in the tactical and technical problem areas of camouflage, countersurveillance, and counter target acquisition. These capabilities have as their purpose the denial or degradation of hostile surveillance of friendly forces so as to deny, degrade, deceive, delay, or otherwise interfere with enemy target acquisition or analysis of information about these forces, their strength, materiel composition, location, and intent. For purposes of this paper, the terms camouflage, countersurveillance, and counter target acquisition may be used interchangeably depending on the tactical situation being discussed but camouflage* is considered the more inclusive term.

New emphasis is being placed on ways of achieving camouflage and deception to provide improved security and survival for U. S. Army forces in the field. New and improved techniques and devices are being developed to augment and complement present camouflage materiel, methods and procedures. All such techniques and devices will require evaluation and assessment to determine their contribution to mission success and their effectiveness for achieving camouflage goals. Various means may be selected to perform these evaluations, including laboratory tests, modeling, simulation, gaming, field experiments, and field exercises. In any case, suitable measures of effectiveness will be required to accommodate the various levels of perspective from which camouflage may be evaluated.

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* Camouflage, as defined in AMCR 70-58, can be summarized as the use of concealment (the intentional denial to surveillance of an object, signature, signal, or other evidence normally through blending, hiding, and disguising) to minimize the probability of detection and/or identification of troops, materiel, equipment, and installations.

Fundamentally, what is required as a basis for selecting measures of effectiveness is a thorough definition and appreciation of the camouflage assessment problems in all aspects. The definition and assessment represents an initial step toward the development of reliable and comprehensive means of evaluating camouflage and deception effectiveness (e.g., through modeling, simulation, gaming, and tests) with full regard for the concerns expressed about the uses, limitations, and constraints of existing evaluation tools and techniques.

The Measures Problem

Camouflage and deception, as applied in the context of counter-surveillance and counter target acquisition, are intended to improve the combat effectiveness of ground forces. A principal question is, How to measure this contribution to the combat effectiveness of a force? By relating changes in the battle outcome to changes in the characteristics of camouflage and deception systems? By relating changes in survival ratios, with and without camouflage and deception, to the range and search times for target detection/recognition, or the probabilities of detection/recognition/identification? What means are available now to analyze simulated combat that are also sensitive to camouflage and deception characteristics?

It is important for these purposes to generate convincing arguments and quantitative results that show whether camouflage and deception can be cost-effective elements in interacting with opposing sensors and tactical forces. There is need to show whether a commander, who can effectively deceive the enemy as to his location, strength, and intentions, increases his chances of survival on the battlefield. As surveillance, target acquisition, and tactical weapons become more sophisticated, the detection, recognition, and identification of firepower elements, important materiel items, and installations virtually assures their destruction.

The term, "measures of effectiveness", is used to denote an indicator or index of some desired accomplishment or effect. The measure has dimensions of amount or capacity, or degrees of something ascertained to be in fulfillment of that desired effect. The overall measure of effectiveness serves as a basis or standard of comparison, or as a criterion comparing the measured quantity with a standard or with other measures of like kind.

The measures of effectiveness (MOE) of interest here are those capable of indicating the degree of success or accomplishment of camouflage and deception in the countersurveillance and counter-target-acquisition (CS/CTA) application in any given set of conditions. The purpose of these passive countermeasures is to inhibit or degrade hostile surveillance of friendly targets; hence, the MOE are expected to show that degradation in relation to some camouflage or deception characteristic, and/or the effects such degradation may have on combat mission success.

The preceding paragraph contains deceptively simple statements about an exceedingly complex situation. Success depends on a large number of variables that can significantly influence both the immediate sensor-target interaction and the consequences in terms of combat results. Examples are illustrated in the following table.

TABLE 1. EXAMPLES OF VARIABLES AND MOE
IN THE CAMOUFLAGE/DECEPTION SITUATION

Variables	Measures of Effectiveness
Target signatures	Signal/contrast thresholds
Tactical engagement situation	Geometry/line of sight
Environmental factors	Weather/illumination
Quality of hostile surveillance	Number/sensitivity of sensors
Tactics of hostile surveillance	Location/coverage of sensors
Performance of enemy intelligence system	Timeliness/accuracy of intelligence

Each of these situation variables introduces its own set of possible measures that can describe some aspects of the CS/CTA problem. Because of this complexity, it is not surprising to find that it is impossible to state *any single measure of effectiveness* that is useful in directly evaluating more than a few situations at one time or more than a limited segment of the wide spectrum of possible camouflage and deception concepts that might be employed in these situations.

Furthermore, the camouflage and deception concepts themselves make measurement complicated. The systems devised to accomplish these concepts are supportive rather than primary in their combat roles. These systems do not contribute directly to firepower or mobility or to any other direct effect in accomplishing the combat mission. Instead they contribute indirectly to the achievement of the combat mission in a number of ways, such as enhancing the survival of primary firepower, enabling movement with reduced materiel losses, or reducing casualties during the combat engagement. Measures of effectiveness thus must measure both the direct performance of the CS/CTA systems, in terms of reduced target detection/recognition/identification, and the indirect or consequential performance effects, in terms of increased survival and reduced materiel/personnel losses. Obviously at least several MOE are required to do this for any given system concept.

Concepts of Measurement

The concepts of measurement applied in an examination of camouflage and deception are fundamental in defining appropriate measures of effectiveness. These concepts may embrace, on the one hand, theoretical or abstract expressions of relationships among the various camouflage parameters; or, on the other hand, they may reflect experimental measurements made by direct means in observations of real or analog camouflage devices and operations.

The entire realm of the measures of effectiveness environment is aptly illustrated in Figure 1. On the left in this figure are the more theoretical or abstract areas of analysis and the analytical techniques applied in conducting quantitative inquiry into the character and performance of camouflage and deception system structures and their elements. In this area, the measures of effectiveness tend to be well defined, and in fact are an integral part of the analysis structure itself. It is this area of MOE and systems analysis with

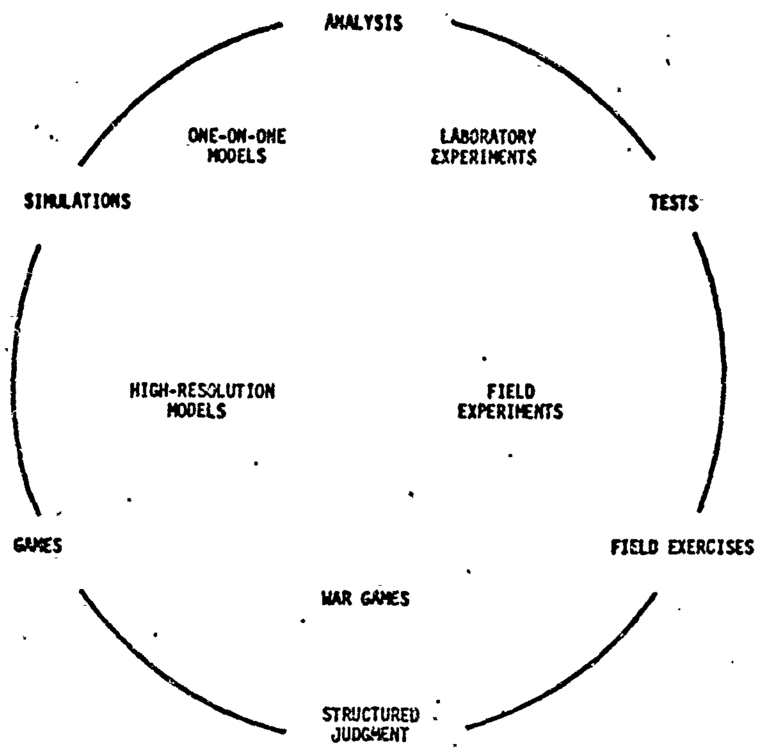


FIGURE 1. THE MEASURES OF EFFECTIVENESS ENVIRONMENT

which this report is primarily concerned. Normally the process of analysis would employ models, i.e., abstract representations of reality which are used for the purpose of prediction and the development of an understanding about the real-world processes. Processes in which appropriate MOE would be used in this context include

- Analysis: Analytical models comprised of sets of mathematical equations that "model" all the basic events and activities of the process being described; an overall assumed mathematical structure of the process into which the event or activity descriptions are integrated.

- One-on-one models: Deterministic or probabilistic models which contain events and variables that define the interaction between sensors and targets, either singly or in combination.

- Simulations: Models representing events in different combat processes, essentially in sequence, with decisions based on predetermined rules programmed into the automated evaluation procedure.

- High-resolution models: Models used to describe the basic combat processes of firepower, mobility, intelligence, logistics, and command and control, with the level of detail (or smallest unit considered as a basic element) down to battalion, company unit, or individual weapon; estimate the output of combat engagements in terms of casualties, survivors, resource expenditures, terrain controlled, etc.

- Games: Models of conflict situations in which opposing players decide upon the courses of action to follow on the basis of their knowledge about their own situation and intentions and information (incomplete to some degree) about their opponent's courses of action.

- War games: Models and game play in which individuals simulate decisionmakers in real life, using their judgment to perform decision functions within the events or activities represented.

- Structured judgment: An ordered process of systematically describing the events and relationships in a combat scenario; provides a qualitative rationale for cause and effect that permits assessment of the progressive states of friendly systems, threat systems, and the combat environment as the combat events unfold; determines preferred alternatives (e.g., systems and their performance) on the basis of mission, resources expended, and estimated engagement outcome.

On the right-hand side of the MOE environment depicted in Figure 1 are the experimental areas in which valid data for evaluating MOE are obtained. In this area, the measurement concepts are those associated with the experiment, test, or exercise. At the laboratory experiment and test level, the MOE take the form of test statistics that describe specific performance variables. Typical examples might include line-resolution limit of an optical array, modulation contrast under given brightness conditions, signal-to-noise ratios, reflected energy levels, and similar physical parameter measures. Such measures are described more fully in subsequent sections of this report.

Field experiments and field exercises introduce a still broader category of measurement concepts having to do with how well camouflage and deception systems are used by troop units under more or less realistic conditions. Statistical measures typically include detection range, search time prior to detection or recognition, the number and rate of targets detected and located, percentage of decoys discriminated, tactical intelligence performance in terms of number and percent of targets correctly identified, incorrectly identified, or missed entirely, etc. In addition, there are also subjective judgment measures

that may be applied to: achieving mission objectives, the ease of tactical maneuver, or the ease or difficulty of mission accomplishment when camouflage or deception techniques are employed. In complex tactical situations, it is not expected that all significant factors can be quantified. Assessment of camouflage and deception in the field will always involve command judgments about the contribution of these elements to favorable or unfavorable conditions in the combat engagement.

Levels of Measures of Effectiveness

It is clear that for broadly applied and pervasive system concepts, such as camouflage and deception, there are many possible concepts of measurement and, associated with these, many possible measures of effectiveness. The choice of MOE will depend on the system being examined, the method used to perform the examination, and the viewpoint of the evaluator. The choice of MOE will largely determine what is important and what is not.

What, then, are the kinds of MOE appropriate for assessment of camouflage and deception? What are the most relevant levels of MOE consistent with the evaluator's perspective of the camouflage and deception problems? Researching these questions in detail has led to the conclusion that there is no single level, single assessment step, or single measure of effectiveness that is adequate for all purposes or all viewpoints. Instead there is a series of assessments corresponding to the scope (perspective) or level of the questions being asked about the camouflage and deception problem and all of its ramifications. Figure 2 illustrates an assessment hierarchy constructed of such a series of assessments with MOE for design, systems operations, tactical operations, and force levels.

The assessment steps begin at the lowest, or basic technology, level with the narrowest, most limited questions, and expand to the highest or combat-outcome level with the broadest, most inclusive questions. Each step up from lowest to highest is dependent on the preceding step for evaluating the camouflage and deception performance parameters needed to quantitatively resolve the events and activities at this next higher aggregation level. This sequence of assessment and MOE corresponds to the ascending order of perspective, increasing in scope and generality from detailed design assessment up to assessments of the

military worth of camouflage and deception. The latter are more important in support of decisions on resource allocation and force studies at the highest decision levels.

At the design level, technology is especially important in determining the relationship between the sensor and the target. At this level, effectiveness is most clearly described in terms of technical performance parameters and physical phenomena, such as the materials properties of the camouflage/deception designs, apparent target-to-background contrasts, and sensor/detector responses to specific target signatures. The systems operations level extends the design viewpoint further into the mission configuration, elaborating on the designs and their applications in CS/CTA. Performance is assessed through systems operations measures in one-on-one system models or in tests of the camouflage systems in operations context. The system capabilities of the sensors (visual/photographic, infrared, radar, acoustic, seismic, and chemical) relate directly to the target perceptibility in such effectiveness measures. At the next higher tactical operations level, the tactical maneuver, firepower and environment enters into effectiveness in the form of engagement conditions, probable detection ranges, time rate of target acquisition, detection/recognition/identification by surveillance means, and the consequences of these events, such as probability of survival of the target with or without camouflage. At the higher echelon decision or force levels (e.g., Headquarters, Army Materiel Command and Headquarters, Department of the Army), effectiveness relates to the military value of camouflage and deception in comparison with many other options that may be exercised to improve combat effectiveness. The measures of effectiveness at this level deal with questions such as: "How much is the combat effectiveness of a ground force changed when camouflage and deception are added to the force?"; "How does the change in effectiveness from improved camouflage and deception compare with that from an equal cost addition of maneuver elements?" Successful development and conduct of a camouflage and deception program is critically dependent on clearly defining effectiveness by means of appropriate measures and being able to illustrate quantitatively through modeling, simulation, and analysis that camouflage and deception can make a legitimate contribution to the future effectiveness of a field army.

It is further concluded that any one of the assessment steps in the series cannot by itself satisfy the decision requirements. Each level of assess-

ment illustrated in Figure 2 has unique requirements for input data, scope and detail of assessment, MOE, and output in terms of value statements corresponding to the level of perspective of the evaluator.

The models and assessment methods indicated in the several assessment blocks are discussed in subsequent sections and appendices of this report.

In summary, the four useful levels of MOE are shown in Table 2 in correspondence with the several perspectives that address the problem of measuring the value of camouflage and deception. In general terms, the input, methods of analysis, and output associated with each perspective and level of MOE proceeds upward from the design level with the output of each level providing input to the next one above.

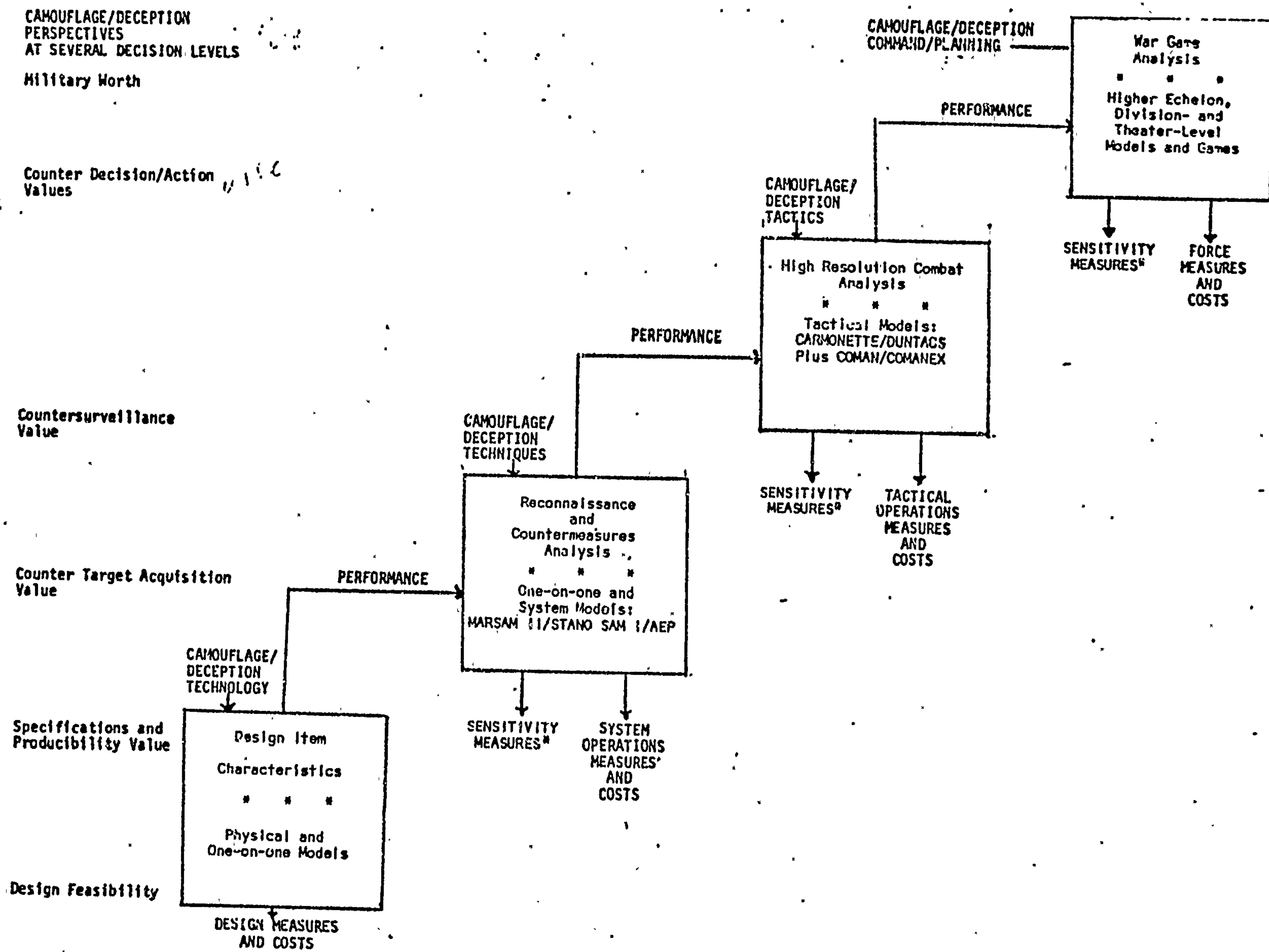
If further breakdown of the levels of MOE is required, it would be reasonable to subdivide the design measures into several categories depending on the state of development of the particular item being considered. In addition, at the tactical operations level, suitable intelligence measures of effectiveness as they are developed can be reasonably considered as a logical subdivision in the levels of MOE.

Design Measures

The measures of effectiveness at the design level are specifically related to the design item characteristics. Basically, they are concerned with design feasibility, specification, and producibility. Measures on this level tend to be uniquely associated with particular camouflage/deception designs. They naturally depend rather specifically on certain technical relationships and are difficult to generalize.

Measures of quality, as compared with some appropriate standard, are forms of effectiveness statements*. These are basic measures useful in the camouflage problem. They are too numerous and too well known to describe here in detail.

* e.g. in electromagnetics: scatter cross section, conductivity, propagation, polarization; in optics: absorption, diffraction, emission, resolution; in radiometry: irradiance, reflectance, spectral emittance; in photometry: luminous intensity, brightness, photoemission, photoconductivity.



* Marginal changes in input parameter values or assumptions are made in order to ascertain the effect these changes have on model output.

FIGURE 2. AN ASSESSMENT HIERARCHY

TABLE 2. LEVELS OF MEASURES OF EFFECTIVENESS (MOE)

Camouflage/Deception Perspectives	Input	Methods of Analysis	Levels of MOE	Output
Military Worth	Tactical system performance Camouflage/deception doctrine/tactics	War games Field exercises Judgment	Force measures	Force performance
Counter Decision/Action Value	Tactical system performance Camouflage/deception tactics/techniques	War games Field tests Judgment Intelligence analysis	Tactical operations Measures (Intelligence measures)	Force performance Intelligence system performance
Countersurveillance Value	Design item/system performance Camouflage/deception performance and tactics/techniques	High-resolution combat analysis One-on-one models Field tests	Tactical operations measures System operations measures	Tactical system performance
Counter-Target-Acquisition Value	Design item/system performance Camouflage/deception tactics/techniques	High-resolution combat analysis One-on-one models Field tests	Tactical operations measures System operations measures	Tactical system performance
Specification/ Producibility Value	Technology Design item qualities	Quality/producibility tests	Design measures (Quality/performance)	Design item/system performance
Design Feasibility	Technology Design techniques	System/design analysis	Design measures (Quality/performance)	Design item/system characteristics

Measures of performance on the other hand imply some function to be performed, e.g., contrast reduction or target signature change. The designer routinely approaches this problem with some particular goals and conditions in mind. He notes the camouflage/deception objectives, the threat, and the environment, and selects possible approaches for analysis, experiment, and test. This process and the design MOE related to performance might take the form illustrated in Table 3. For the equipment items of interest, the mission/objective is to deny, reduce, or dilute detection by hostile sensors. The target signatures and cues exposed to the hostile sensors in the engagement scenarios form the basis for analyzing the camouflage/deception problem. Consideration also must be given to other alternative ways of protecting the equipment items in the given environment. The design approach selected is then implemented, analyzed, and tested, utilizing measures of effectiveness of the kind indicated in Table 3.

Following through the remainder of the design procedure, it is obvious that there are many "measures" that may be applied to compare and select a preferred design. Some of these measures may be used as MOE.

Although design measures expressing quality and performance at this lowest level in the assessment hierarchy are fundamental in the evolution of camouflage/deception capabilities, it is not difficult to see that effectiveness, as viewed from different perspectives, cannot be estimated or assessed without projecting the design approach forward, at least through the systems operations and tactical operations levels, where the consequences of performance can be assessed. This is what the assessment hierarchy (Figure 2) indicates must be done to satisfy evaluation needs at various levels. In practice this is accomplished initially as part of the design process, utilizing the analysis techniques of modeling, simulation, and gaming prior to design tests to assess design results and design alternatives.

System Operations Measures

In the previous discussion, systems MOE have been treated in a more or less general manner, so as to show their variety and how they relate to different levels of perspective on the problem of camouflage and deception. In order to be more specific, it is useful to concentrate on a particular level of analysis.

TABLE 3. ELEMENTS OF A CAMOUFLAGE/ DECEPTION DESIGN PROCESS

Design Process	Elements
State Goals/Missions/ Objectives	Identify equipment items of interest as target objects to be camouflaged Conceal from (deny item detection by) hostile sensors Deceive (reduce item detection by) hostile sensors Confuse (dilute item detection by) hostile sensors
Define Threat and Environment	Hostile sensing techniques Target signatures Engagement environments Alternatives to camouflage/deception
Select Approaches	Materials which reduce target contrasts Equipment item designs which reduce target signatures Techniques which confuse sensor systems
Choose Measures of Effectiveness	Reduction of apparent target-to-background contrasts (ratio of object/shadow reflectance to background reflectance) Reduction of display target-to-background contrasts Reduction of sensor contrast-to-contrast-threshold ratios Reduction of emissivity of the target Reduction of pattern correlations Reduction of signal-to-noise ratios Increase in false-alarm rates
Proceed with Design	Material selection Efficient design Weight minimization Cost minimization Environmental ruggedness Analysis of design effectiveness Analysis of design tradeoffs Manufacturing process selection Specification compliance Maintenance minimization Other design/development requirements (e.g., human factors, safety, packaging, transportability, etc.) Test and evaluation

System operations measures, and the sensitivity measures associated with them, are outputs of the one-on-one models and simulation models that are used to analyze reconnaissance and the countermeasures that may be used for camouflage and deception against the reconnaissance threat. The one-on-one models may be deterministic or probabilistic models which contain events and variables that describe the interactions between sensors and targets either singly or in combination. Simulation models are those which represent events in a variety of combat processes, essentially in sequence, with decisions based on predetermined rules that are programmed into the automated evaluation procedure. The analyses using these models define particular situations and environments in which the overall effectiveness of a camouflage/deception system of a specific design can be evaluated. Typically the input to these models would define sensor characteristics and performance, target elements and their signatures, background signatures, terrain or line-of-sight calculations, weather conditions, and characteristics and attributes of the camouflage/deception techniques being employed. The latter might include paints, nets, smokes/aerosols, indigenous materials and terrain features, mirrors, visual scattering devices, microwave absorbents, and optical/geometric/heat decoys, etc. Output in the form of system operations measures might include probabilities of detection/recognition/identification, signal-to-noise ratios, contrast ratios (reflectance or emissivity) and false alarm rates related to decoy detection, etc.

The number of possible measures that can be useful as system operations measures is naturally large. Many of these same measures can be used as sensitivity measures. A sensitivity analysis is simply a procedure whereby modular changes in input parameter values or assumptions are made in order to ascertain the effect these changes might have on the results of model output.

It is instructive to observe the number and variety of measures that may be associated with the sensor-target interaction processes in camouflage and deception. Table 4 lists a number of factors, many of which may be useful as measures for effectiveness comparison in the areas of visual, infrared, and radio frequency processes. The factors are divided according to how they are used in the analysis process; i.e., descriptors, process variables, comparison variables, and decision variables. Depending upon the problem being analyzed, many of these factors measure the sensitivity or system operations performance of a given camouflage/deception technique.

TABLE 4. POSSIBLE MEASURES OF EFFECTIVENESS ASSOCIATED WITH THE SENSOR-TARGET INTERACTION PROCESSES IN CAMOUFLAGE AND DECEPTION

Sensors	Descriptors	Variables: Process	Variables: Comparison	Variables: Decision
Visual				
Camera	Dimensions, m Reflectivity Camouflage contrast degradation factor Numbers and deployment	Areas (physical plus shadow) Inherent and apparent brightness (for target and shadow) Exposure on film (target and shadow), m/c-sec Ground resolution (target and shadow) Illumination in shadow, ft/c Number of ground-resolved lines across target and shadow Shadow clarity factor Conditional P_D, P_R, P_I	Modulation contrast (target and shadow)	P_D, P_R, P_I Probability of element shadow detection
TV	Dimensions, m Reflectivity Numbers and deployment	Maximum and minimum dimensions (plan dimensions, on display), m Target-element apparent brightness, c/ft^2 Display brightness from target-element, fL Maximum and minimum brightness of target-element or background, fL Target-element inherent brightness, c/ft^2 Photocathode illumination from target-element, fc TV pickup tube output current from target-element, amp Number of ground resolved lines across target-element Target-element time in view, sec Display input voltage due to target-element, v	Target-element-to-background apparent contrast Target-element-to-background contrast on display Output signal-to-noise ratio	P_D, P_R
Observer	Dimensions, m Reflectivity Numbers and deployments Density and number of confusing objects, objects/m^2 Camouflage contrast degradation factor Angular velocity of target-element with respect to observer	Dimensions (average projected, size), m/min of arc Target-element apparent brightness, c/ft^2 Target-element inherent brightness, c/ft^2 Target-element distinctiveness coefficient Expected number of glances required to bring viewing on a target Number of visual acuity elements across target-element Conditional P_D (size and contrast, confusing objects, visual search mode), P_R Increase in acuity with angular velocity Total plan area of all target elements within target, m	Target-element/background contrast Contrast-to-contrast-threshold ratio	P_D, P_R
Infrared	Dimensions, m Emissivity Camouflage area degradation factor Temperature, K Numbers and deployment	Areas (physical, "effective", on display), m^2 Brightness (display), fL Film exposure, m/c-sec Number of resolution elements contained within target-element Received power, w Conditional P_D, P_R, P_I Film Display voltage input for target-element	Display contrast Signal-to-noise ratio	P_D, P_R, P_I Probability of "hot spot" detection

TABLE 4. (Continued

Sensors	Descriptors	Variables: Process	Comparison	Decision
Radio Frequency				
MTI Radar	Dimensions, m Radar cross section, m^2 Camouflage effective radar cross section degradation factor Velocity, knots Numbers and deployment	Areas (physical, effective), m^2 Power density at the target-element, w/m^2 Received target-element power, w Conditional P_D Target-element reflected power, w Target-element power at filter input, w Number of target elements in a ground-resolved cell Average number of like elements in a ground-resolved cell Target-element time in view, sec Target-element radial velocity, knots Target-element relative bearing, degrees Effective target-element radar cross section, m^2	Receiver signal-to-noise ratio Signal-to-noise ratio, db	P_D
Non-MTI Radar	Dimensions, m Radar cross section, m^2 Camouflage effective radar cross section degradation factor Numbers and deployment	Areas (physical, effective), m^2 Power density at the target-element, w/m^2 Received target-element power, w Conditional P_D, P_R, P_I Target-element reflected power, w Target-element power at filter input, w Number of target-elements in a ground-resolved cell Average number of like elements in a ground-resolution cell Target-element time in view, sec Effective target element radar cross section, m^2 Number of resolution elements contained within target-element	Receiver signal-to-noise ratio Signal-to-noise ratio, db	P_D, P_R, P_I
ELINT	Coordinates Type of emitter Emitter area of effectiveness, bandwidth, duty cycle, frequency, antenna gain, power, beamwidth, pulse length, rotation period Probability of antenna coincidence for "other" types of radar	Number of emitters $\pm\Delta f/2$ of emitter signal Number of emitters $\pm\Delta prf/2$ of emitter signal Probability of antenna coincidence Probability of frequency coincidence Conditional probabilities (intercepts, identification) Power received from main and minor antenna lobes, w Power received less meteorological losses, w Emitter pulse repetition period, sec	Main and minor lobe signal-to-noise ratio	Probability of intercept Probability of identification Probabilities of intercept and identification for the entire flight path Probability of overload

Tactical Operations Measures

The output of the one-on-one and simulation model analyses normally constitutes the input performance measures and parameters to the tactical level of analysis. In contrast to the detailed physical performance measures at the simulation model level, the tactical operations measures typically evaluate the performance of camouflage and deception tactics in a specific combat encounter situation.

At the tactical level of analysis, there are not as many factors that may be useful as measures for assessment of camouflage and deception effectiveness as there are for system operations. In the high-resolution combat-analysis models, combat results are expressed primarily in terms of weapons survivability, weapon losses, exchange ratios, changes in force ratio, and resources (e.g., number of rounds) expended. However, the relationship between these results and the performance of camouflage and deception in attaining them has not been well developed in most combat analysis models. Depending upon the model design, it is possible to utilize systems measures that contribute to the combat results. These systems measures include the following:

- Probability of detection, recognition, and identification for given sensor/target combinations
- Range of detection, recognition, and identification
- Accuracy of recognition and location
- Search time or effort required to detect, recognize, and identify particular targets
- Statistical measures (e.g., number/percent targets detected, recognized, and identified; number/percent targets undetected; number/percent of decoys or false targets detected, etc.).

It would be desirable to measure the number of false targets later corrected and labeled as false targets during the engagement. Unfortunately none of the existing combat analysis models can assess this important event. Significant modifications of the models would be necessary to accommodate this and other interesting camouflage and deception measures.

Some practical MOE which are appropriate as tactical operations measures are suggested in Table 5. A distinction is drawn between countersur-

TABLE 5. PRACTICAL MOE (BLUE VERSUS RED)[(a)]

Red Offensive Effectiveness (Minimize) (Red Performance Against Blue)		Blue Defensive Effectiveness (Maximize) (Blue Performance Against Red)	
Countersurveillance	**Counter Target Acquisition**	**Countersurveillance**	**Counter Target Acquisition**
No./Percent Blue items/systems • Detected - per unit time (air/ground) - per Red surveillance sortie (air) - per unit range (ground) • Recognized - per unit time (air/ground) - per Red surveillance sortie (air) - per unit range (ground) • Identified - per unit time (air/ground) - per Red surveillance sortie (air) - per unit range (ground)	No./Percent Blue items/systems • Destroyed - per unit time (air/ground) - per Red attack sortie (air) - per unit range (ground)	Average delay time for Red to • Detect • Recognize • Identify after being within threshold range for unprotected Blue item/system (ground sensors only) Average Red effort (sorties) expended to • Detect • Recognize • Identify after being given cues to Blue item/system location (air sensors only) No./Percent non-real targets that Red • Detects • Recognizes as real • Identifies as real - per unit time (air/ground) - per Red surveillance sortie (air) - per unit range (ground)	Average survival time of Blue item/system Average Red effort expended to destroy Blue item/system • Rounds • Sorties No./Percent Red effort diverted to non-real targets • Rounds • Sorties

(a) Measurements: Clock (time); scale (distance); counter (number).

veillance measures and those more appropriate for counter target acquisition. This distinction is based on the observation that countersurveillance is intended to gather intelligence, whereas counter target acquisition is intended to provide fire direction for destruction of the targets.

On the left in Table 5 are the MOE concerned with the friendly Blue forces' attempts to minimize the enemy Red offensive effectiveness. Each MOE implies that some effort is required by Red to accomplish his purpose. This effort is expressed in terms of time, sorties, or closure distance (range). If Blue can reduce the numerical value of the MOE by any means, then Red offensive effectiveness is reduced.

On the right in Table 5 the friendly Blue forces' attempts to maximize defensive effectiveness are again expressed in terms of time and effort required by Red to achieve his purposes. The MOE contain several qualifications with regard to the threshold conditions under which the defensive effect is being measured. These are self-explanatory in the table.

The MOE described in Table 5 are statistical in nature and require only a clock, a scale, and a counter to perform the measurements. If MOE of this kind can be developed further (certainly there are many other possibilities) and incorporated in high-resolution analysis models of suitable design, it should be possible to obtain the necessary validation of analysis results through field measurements that would have a minimum of complexity.

Force Measures

Measurement of the effectiveness of a military force is largely a matter of judgment by experienced military commanders. Force effectiveness depends on many factors, not all quantifiable, that make up the tactical maneuver, situational conditions, command response, and human elements involved in the combat process.

As an aid in force planning and in analyzing doctrinal and contingency problems, war gaming techniques have been developed that provide context, algorithms, and model structure to predict the results of division- and theater-level combat. These results are generally expressed in terms of territory controlled (e.g., FEBA locations) and resource consumption (e.g., casualties and equipment losses) as a function of various force levels, force mixes, and force

employments. At the high level of aggregation in the division- and theater-level models which were examined for camouflage and deception assessment, it is not surprising to find that MOE which clearly express the consequences of camouflage and deception are nonexistent.

Typical MOE and their definitions as employed in the high-resolution models and war games are shown in Table 6. Evaluation of tactical details, like camouflage and deception, is simply not considered in any direct way in these highly aggregated models. Except for the possible insertion of these techniques through controlled input (predetermined cause and effect), the war games structure at division- and theater-levels cannot accept details of this kind directly. The possibility remains of applying simulation and high-resolution analysis results, determined off-line, in support of particular elements or phases of the war games as is now done for certain armor, weapons, and small-size unit engagements in conjunction with gaming studies. To accomplish this for camouflage and deception will require explicit determination of the relationships between MOE for camouflage and deception performance and the MOE in Table 6 which describe battle outcomes.

The most obvious shortcoming in attempting to assess camouflage and deception effects on battle outcomes is the absence of well-understood models of the intelligence processes through which order-of-battle is obtained, and targets are acquired and destroyed. This is particularly important in evaluating countersurveillance as an inhibitor in enemy perception of the true state of things in the combat situation. The underlying process of "target development" basically consists of two steps:

(1) Detect, recognize, and identify (and locate) the opposing forces in time and space .

(2) Develop information on the activity of those forces.

This is a continuously evolving process and an "intelligence" model of the surveillance-countersurveillance interactions would necessarily have to account for the time-effort variations in intelligence collection, as well as the interpretation-processing variations in intelligence estimates.

TABLE 5. TYPICAL MEASURES OF EFFECTIVENESS AND THEIR DEFINITIONS

Model Type	Measure of Effectiveness[a]	Definition
High Resolution	Blue weapon survivability (usually by type of weapon)	$\frac{\text{Number of Blue losses of weapons of this type}}{\text{Initial number of Blue weapons of this type}}$
	Weapon exchange ratio (usually by type of weapon)	$\frac{\text{Red losses of weapons of this type}}{\text{Blue losses of weapons of this type}}$
	Change in weapon force ratio (may be by weapon type)	$\frac{\text{Blue weapon survivors}}{\text{Red weapon survivors}} \quad \frac{\text{Initial Blue weapons}}{\text{Initial Red weapons}}$
	Weapon system losses (Blue or Red)	A count of the number of weapons of a given type lost during engagements. In some cases, it may be stratified into type of kills, such as a mobility, firepower, mobility and firepower, or total kill.
	Battle time	The time duration of the battle
	Number of rounds fired by type of firer	A count of the number of rounds (by type of round) fired by each weapon type.
Division Level/ Theater level	Territory gained or lost	Measured through the movement of the FEBA, or an expression of the terrain gained or lost during the battle.
	Consumption of resources	The types of resources played not only vary between models but for a given model they will vary from scenario to scenario, based upon changes in force structure, tactics, purpose of the simulation, etc. In most models, counts are maintained of the resources consumed such as weapons (by type of weapon), manpower, ammunition, POL, etc.
	Statistics from battle assessments	In most higher level (above battalion level) games and simulations, battle assessment is determined based upon force ratios and firepower scores or by computing casualties and movement directly. In making these determinations, preselected outcome statistics may be maintained for individual battles and/or for aggregate outcomes for all battles or categories of battles.
	Other statistical summaries	Normally the battle listing is maintained which will permit the tracing of events during the game or simulation. Statistics may be derived using the historical data.

(a) Normally, the primary output of high-resolution models is a chronological listing of events which can be used to derive statistical summaries. The particular statistical summaries (MOE) are usually selected based upon the purpose of the analysis. The MOE listed for the high-resolution models are some of the more typical summaries.

At present, one could simply count the number/percent of the tactical units or discrete targets detected and correctly recognized/identified over some time period as a measure of hostile intelligence effectiveness, and conversely, the performance of countersurveillance measures. A gross MOE of this kind is hardly sufficient for more than a cursory evaluation of camouflage and deception, if indeed the highly aggregated war game analyses would be sensitive at all to reasonable variations in tactics and techniques of this kind.

It must be concluded for now that there are no completely suitable MOE to apply to the counter decision/action level. This represents a serious deficiency in present capabilities to evaluate and assess camouflage and deception contributions to force performance and battle outcomes.

Summary

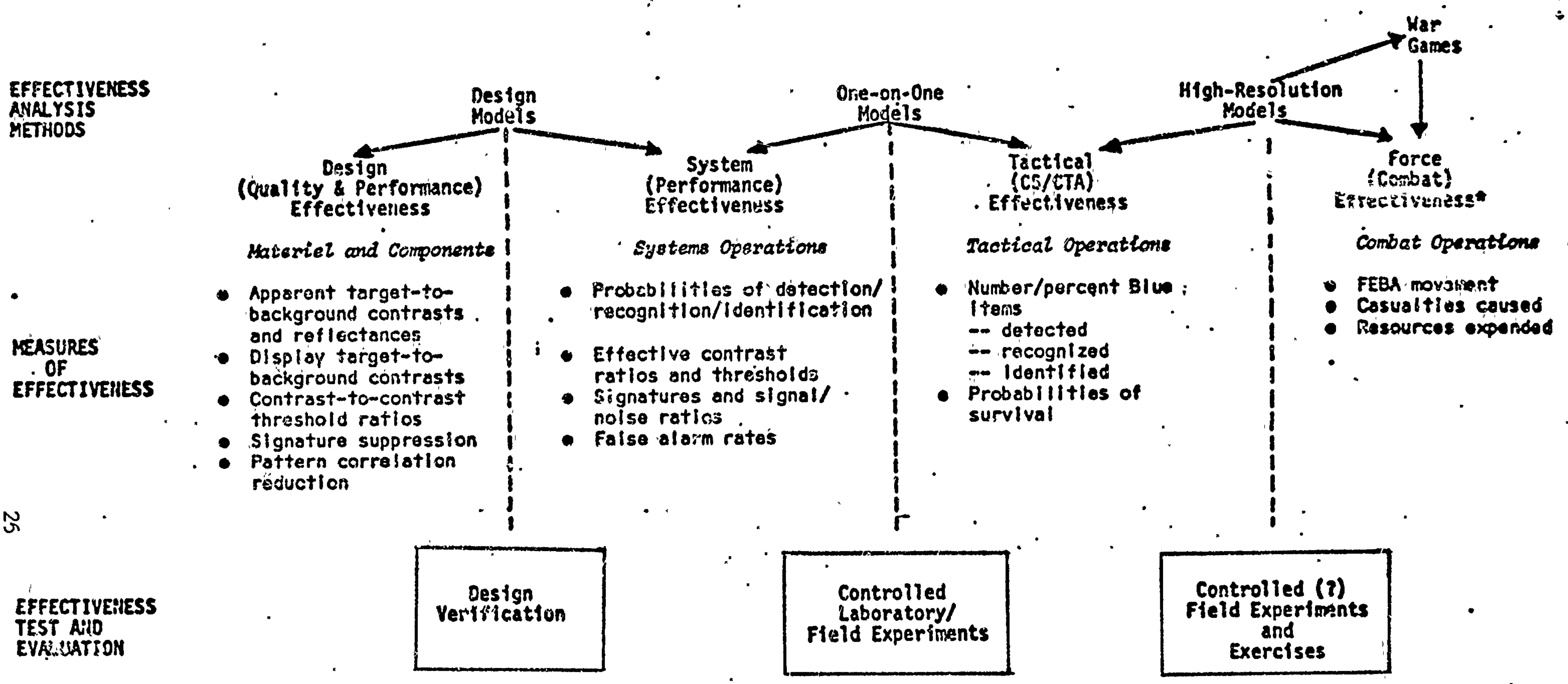
The preceding review of the subject "measures of effectiveness", as it pertains to camouflage and deception, reveals a general structure relating various parts of the subject to one another. The structure as developed in this study is illustrated in Figure 3.

The four levels of MOE are identified as follows:

- Design (Quality and Performance) Effectiveness
- Systems (Performance) Effectiveness
- Tactical (CS/CTA) Effectiveness
- Force (Combat) Effectiveness
  (Includes Intelligence Effectiveness)

At each level there are appropriate measures that can be applied to quantify performance so that effectiveness can be assessed and alternative ways of doing the camouflage/deception job can be compared.

There is no single MOE that will describe all the qualities that are desired. Different perspectives or perceptions of the camouflage/deception needs cover too broad a range. Figure 3 shows clearly that full consideration of all design questions at the design level should consider not only the first-order capabilities, such as contrast reduction and signature suppression, but higher order measures that deal with systems, tactics and force effectiveness. To do



* Includes intelligence system effectiveness.

FIGURE 3. STRUCTURE OF MEASURES OF EFFECTIVENESS

this at the design level means that analysis, simulation, and gaming tools at least through the one-on-one and high-resolution models must be used. These analysis methods serve as transition media from one level to another and must be developed to a point where they have credibility and acceptance in the design community. Each method and/or model requires input performance parameters and quantities from lower level models so that the progressively greater aggregation, less detail, and broader scope viewpoints can lead to understanding of camouflage effectiveness at the real-world combat (force) level of analysis.

Of course these steps cannot be accomplished without performing the corresponding effectiveness test and evaluation activities at each level. Effectiveness T&E must provide the necessary validation of the analysis models and the experimental/test data to verify the design and the systems, tactical, and force performance measures. Effectiveness test and evaluation activities, using the same MOE as the analysis models insofar as possible, should proceed simultaneously with the effectiveness analysis at each MOE level.

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